

# What really are the best 100m performances?

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The title of the “Fastest Man in the World” has always resided in the domain of the 100m champion. There is perhaps no greater test of strength, power, and agility for a human being. In late July 1997, this title returned to its home in Canada as our own Donovan Bailey crossed the finish line in a remarkable 9.84s, even after a relatively slow reaction time of 0.174s and a small tail wind of +0.7 m/s. His incredible top speed of 12.1 m/s is further support to his claim on the title.

However, this race was run with a non-zero tail wind. That is, Bailey had an advantage not over his competitors, but over 100m times from other races. While the legal wind speed limit is +2.0 m/s for the 100m and 200m sprints, one can never discount the fact that a race run with a +1.9 m/s tail wind has an implicit advantage over a race run with a 0.0 m/s tailwind, or even a headwind, for that matter. Despite these rules, is it possible to compare *all* 100m races on a more or less equal footing?

The answer, to a degree, is “yes”, and results from a little application of the physics of fluid mechanics. A runner moving through a wind with an arbitrary velocity experiences either a resistive or propulsive force, as well as a drag effect. The former are the result of Newtonian mechanics (force laws), and the drag depends on such factors as the runner’s mass, speed, cross-sectional area, and density of surrounding air.

It was determined that a sprinter loses between 3–6% of his/her energy in overcoming the drag. A simple formula to compensate for accompanying wind speeds was derived to calculate the equivalent still-air (zero wind speed) race times; for the conservative limit of 3%, this is

$$t_0 \approx \left[ 1.03 - 0.03 \times \left( 1 - \frac{W \times t_W}{100} \right)^2 \right] \times t_W , \quad (1)$$

where  $t_W$  is the recorded race time,  $W$  is the wind speed, and  $t_0$  is the equivalent still-air time. You can do it with your own race times!

So, how would the record books look if this formula was a standard application to world class performances? Adjustments of various sets of 100m times (denoted by  $t_0$  and  $t_W$ , respectively) are shown in the accompanying

tables. For sheer comparison, Ben Johnson's disqualified WR performances of 1987 and 1988 are included.

## 1 World Rankings

One of the most fascinating results can be found in Table 2, the wind-corrected performances. Donovan Bailey's 9.84s WR adjusts to a 9.88s equivalent in calm air. Meanwhile, Frank Fredricks' 9.86s clocking (Lausanne, 03 Jul 1996) was run with a wind reading of  $-0.4$  m/s, which after correction surpasses Bailey's WR performance by 0.04s! It is certainly conceivable that, given the proper conditions, Fredricks could have claimed the elusive title of "World's Fastest Man" with this race. In fact, if Fredricks had given this same performance in Atlanta (*i.e.* with a wind speed of  $+0.7$  m/s), he would have crossed the line in roughly 9.81s!

It should be noted that, due to the drag effects mentioned earlier, races run into a head wind will have faster corresponding times than races run with a tail wind of equivalent strength. Figure 1 shows that the "correction curve" is not linear, but rather a curve bending toward the right. Hence, a head wind will fall on the "steeper" portion of the curve, while a tail wind will be on the shallower side.

The 9.84s WR would rank 6th all-time if we included banned performances (Table 3). After correcting for the wind conditions, (Table 4), this time climbs to 5th, but is surpassed by several different performances. Thompson's 9.69s run has a wind-corrected equivalent of 9.93s, and has sunk to 16th. Meanwhile, Davidson Ezinwa's 9.91s race (into a 2.3 m/s headwind) has a wind-corrected 9.76s equivalent. Note that this performance is marked with a "d", indicating a doubtful wind reading<sup>1</sup>.

Florence Griffith-Joyner's 100m WR performance of 10.49s at the 1988 US Olympic Trials is skeptical. It has been noted that, at the time of this race (second heat of the second round), the wind gauge for the 100m straight read a speed of  $+0.0$  m/s, whereas a nearby gauge (for the jumps runway) read speeds in excess of  $+4.0$  m/s. Furthermore, the wind reading for the third heat was  $+5.0$  m/s. This mysterious sudden calm was never really addressed; it is unreasonable to assume that the wind would die down

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<sup>1</sup>It is generally known that athletes who race at altitude perform better than they do closer to sea level, and it has been suggested that this effect may be more physiological in nature than physical, since the corresponding change in air density does not yield the expected change in race time.

completely for the duration of one race. So, assuming that the wind speed was actually between +4.0 m/s and +5.0 m/s during Flo-Jo's "WR" race, she would have actually clocked a time somewhere in the range of 10.70s – 10.74s for a still wind, which would be much more consistent with her other performances (her time of 10.61s in the final was legal, however, with a wind speed of +1.2 m/s).

## 2 Canadian Rankings

This analysis also shows some neat results of local interest. For example, Bailey's 9.84s WR from Atlanta rounds to a 9.88s still-air equivalent. Furthermore, if the correction formula (1) is applied to Bailey's Atlanta splits<sup>2</sup>, these times could be compared with indoor performances (where there is no wind speed) over the same distance. In this case, one finds 50m and 60m times of 5.63s and 6.53s, respectively. The former (5.63s) is only 0.07s slower than his 50m 5.56s indoor WR (Reno, NV, 09 Feb 1996), a difference which could perhaps be accounted for by reaction time; *i.e.* if Bailey had a reaction time of around 0.11–0.12s for his 50m WR, then these results would be consistent. The latter (6.53s) is 0.02s off his 1997 indoor PB of 6.51s (Maebashi, Japan, 08 Feb 1997). This would tend to suggest that Bailey's Olympic 100m WR was consistent with his other PB performances.

The 1996 100m rankings can be similarly restructured. Table 8 shows the top 46 performances, accounting for wind assistance, and Tables 6,7 show the top 10 legal and wind-corrected rankings. The Canadian rankings do not suffer as much of a restructuring as do the World rankings.

## 3 Conclusions

Who, then, did run the fastest 100m race ever? Based on this model, and discounting substance-assisted performances, doubtful wind readings, and hand-times, Fredricks comes out the winner, and Bailey has to settle for 2nd. Only 3 of the top 20 performances are now sub-9.90, whereas before 8 out of 20 were under this mark. The third fastest wind-corrected time is Christie's; it would have been interesting had he not false-started out of the final in Atlanta. Only about 7 of the top 20 wind-corrected athletes will be

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<sup>2</sup>The formula has to be modified for the distance, though; the '100' in the numerator changes to 50 and 60 to correspond to the race distance. Although, it doesn't make much of a difference to leave it as 100.

competing this year (who knows if Christie will be back with a vengeance?). We'll most likely see the most sub-9.90s races to date. Most importantly, though, Fredricks has the real potential to better Bailey's existing record. Of course, Bailey will also have the same potential. It seems quite likely that the 100m WR drop from its 1996 mark. Will we see a sub-9.80s race? If so, who will be the one to run it? Based on their best races last year, Bailey could run a 9.79s with a +1.7m/s tailwind, while Fredricks would need a mere +1.0m/s! With more training under their belt, who knows what to expect. Watch for a showdown between these two at the 1997 WC!

## References

- [1] *Canadian Athletics Annual: 1996 in Review*, C. Smith ed., Athletics Canada (1997).
- [2] W. G. Pritchard, "Mathematical Models of Running", SIAM Review **35**, 359–379 (1993).
- [3] R. Tibshirani, "Who is the Fastest Man in the World?", *to be published* American Statistician (1996).

#	$t_W$	$W$	Athlete	Location	Date
1	9.84	+0.7	Donovan Bailey CAN	Atlanta, GA	27 Jul 1996
2	9.85	+1.2	Leroy Burrell USA	Lausanne, SWI	06 Jul 1994
3	9.86	-0.4	Frank Fredericks NAM	Lausanne, SWI	03 Jul 1996
4	9.86	+1.2	Carl Lewis USA	Tokyo, JAP	25 Aug 1991
5	9.87	+0.3	Linford Christie GBR	Stuttgart, GER	15 Aug 1993
6	9.87	+1.9	Fredricks NAM	Helsinki, FIN	25 Jun 1996
7	9.88	+1.2	Burrell USA	Tokyo, JAP	25 Aug 1991
8	9.89	+0.7	Fredericks NAM	Atlanta, GA	27 Jul 1996
9	9.90	+0.7	Ato Boldon TRI	Atlanta, GA	27 Jul 1996
10	9.90	+1.9	Burrell USA	New York, NY	14 Jun 1991
11	9.91	+1.3	Bailey CAN	Montréal, PQ	15 Jul 1995
12	9.91	+1.5	Dennis Mitchell USA	Milan, ITY	07 Sep 1996
13	9.91	+1.9	Christie GBR	Victoria, BC	23 Aug 1994
14	9.92	+0.3	Andre Cason USA	Stuttgart, GER	15 Aug 1993
15	9.92	+0.8	Boldon TRI	Eugene, OR	01 Jun 1996
16	9.92	+1.1	Lewis USA	Seoul, SK	24 Sep 1988
17	9.92	+1.1	Mitchell USA	Atlanta, GA	16 Jun 1996
18	9.92	+1.2	Christie GBR	Tokyo, JAP	25 Aug 1991
19	9.93	-0.6	Mike Marsh USA	Walnut, CA	18 Apr 1992
20	9.93	-0.6	Boldon TRI	Atlanta, GA	27 Jul 1996

Table 1: Men's Top 20 fastest legal 100m times, ranked according to increasing tail-wind speed (for equal time runs).

New	Old	$t_0$	$t_W$	$W$	Athlete	Date	
1	3	9.84	9.86	-0.4	Frank Fredericks NAM	03 Jul 1996	
2	1	9.88	9.84	+0.7	Donovan Bailey CAN	27 Jul 1996	
3	5	9.89	9.87	+0.3	Linford Christie GBR	15 Aug 1996	
4	56	9.89	9.97	-1.3	Leroy Burrell USA	01 Aug 1992	
5	57	D	9.90	9.97	-1.2	Ben Johnson CAN	19 Aug 1987
6	20	9.90	9.93	-0.6	Ato Boldon TRI	27 Jul 1996	
8	21	9.91	9.93	-0.4	Bailey CAN	03 Jul 1996	
9	29	9.91	9.94	-0.5	Fredericks NAM	27 Jul 1996	
10	2	9.92	9.85	+1.2	Burrell USA	06 Jul 1994	
11	30	9.92	9.94	-0.4	Boldon TRI	03 Jul 1996	
12	46	D	9.93	9.96	-0.6	Davidson Ezinwa NGR	18 Apr 1992
13	-	w	9.93	9.69	+5.7	Obadele Thompson BAR	13 Apr 1996
14	4	9.93	9.86	+1.2	Carl Lewis USA	25 Aug 1991	
15	8	9.93	9.89	+0.7	Fredericks NAM	27 Jul 1996	
16	37	9.94	9.95	-0.3	Boldon TRI	27 Jul 1996	
17	14	9.94	9.92	+0.3	Andre Cason USA	15 Aug 1993	
18	9	9.94	9.90	+0.7	Boldon TRI	27 Jul 1996	
19	7	9.95	9.88	+1.2	Burrell USA	25 Aug 1991	
20	47	9.96	9.96	-0.1	Cason USA	14 Aug 1993	

Table 2: Men’s Top 20 fastest wind-corrected 100m times, including wind-aided performances (w) and legal times from athletes caught for doping during their career (D).

Rank		$t_W$	$W$	Athlete	Location	Date
1	w	9.69	+5.7	Obadele Thompson BAR	El Paso, TX	13 Apr 1996
2	w	9.78	+5.2	Carl Lewis USA	Indianapolis, IN	16 Jul 1988
3	B	9.79	+1.1	Ben Johnson CAN	Seoul, SK	24 Sep 1988
4	w	9.79	+4.5	Andre Cason USA	Eugene, OR	16 Jun 1993
5	B	9.83	+1.0	Johnson CAN	Rome, ITY	30 Aug 1987
6	w	9.85	+4.8	Dennis Mitchell USA	Eugene, OR	17 Jun 1993
7	w	9.87	+11.2	William Snoddy USA	Dallas, TX	01 Apr 1978
8	w	9.87	+4.9	Calvin Smith USA	Indianapolis, IN	16 Jul 1988
9	w	9.88	+2.3	James Sanford USA	Westwood, CA	03 May 1980
10	w	9.88	+4.0	Bailey CAN	Duisburg, GER	12 Jun 1996
11	w	9.88	+5.2	Albert Robinson USA	Indianapolis, IN	16 Jul 1988
12	w	9.88	+5.3	Maurice Greene USA	Austin, TX	08 Apr 1995
13	w	9.89	+2.9	Mike Marsh USA	Walnut, CA	14 Apr 1995
14	w	9.89	+4.1	Frank Fredericks NAM	Tokyo, JAP	24 Aug 1991
15	w	9.89	+4.2	Raymond Stewart JAM	Indianapolis, IN	09 Aug 1987
16	w	9.90	+3.7	Johnson CAN	Ottawa, ON	06 Aug 1988
17	w	9.90	+5.2	Joe DeLoach USA	Indianapolis, IN	16 Jul 1988
18	d	9.91	-2.3	Davidson Ezinwa NGR	Azusa, CA	11 Apr 1992
19	f	9.91	+1.2	Mitchell USA	Tokyo, JAP	25 Aug 1991
20	w	9.91	+4.2	Mark Witherspoon USA	Indianapolis, IN	09 Aug 1987

Table 3: Men’s Top 20 fastest illegal 100m times, including wind-aided performances (w), doubtful wind readings (d), false starts (f). Ben Johnson’s disqualified WR performances of 1987 and 1988 are shown for comparison.

Rank		$t_0$	$t_W$	$W$	Athlete	Date
1	d	9.76	9.91	-2.3	Davidson Ezinwa NGR	11 Apr 1992
2	h	9.80	9.70	+1.9	Donovan Powell JAM	19 May 1995
3		9.84	9.86	-0.4	Frank Fredericks NAM	03 Jul 1996
4	B	9.85	9.79	+1.1	Ben Johnson CAN	24 Sep 1988
5		9.88	9.84	+0.7	Donovan Bailey CAN	27 Jul 1996
6	B	9.89	9.83	+1.0	Ben Johnson CAN	30 Aug 1987
7		9.89	9.87	+0.3	Linford Christie GBR	15 Aug 1993
8		9.89	9.97	-1.3	Leroy Burrell USA	01 Aug 1992
9		9.90	9.93	-0.6	Ato Boldon TRI	27 Jul 1996
10		9.90	9.93	-0.6	Boldon TRI	27 Jul 1996
11	D	9.90	9.97	-1.2	Johnson CAN	19 Aug 1987
12		9.91	9.93	-0.4	Bailey CAN	03 Jul 1996
13		9.91	9.94	-0.5	Fredericks NAM	27 Jul 1996
14		9.92	9.85	+1.2	Burrell USA	06 Jul 1994
15		9.92	9.94	-0.4	Boldon TRI	03 Jul 1996
16	w	9.93	9.69	+5.7	Obadele Thompson BAR	13 Apr 1996
17	D	9.93	9.96	-0.6	Ezinwa NGR	18 Apr 1992
18		9.93	9.86	+1.2	Carl Lewis USA	25 Aug 1991
19		9.93	9.89	+0.7	Fredericks NAM	27 Jul 1996
20		9.94	9.95	-0.3	Boldon TRI	27 Jul 1996

Table 4: Men’s Top 20 fastest wind-corrected 100m times, including wind-aided performances (w), doubtful wind readings (d), legal performances of athletes caught for doping during their career (D), and disqualified times from athletes caught for doping during their career (B).

#		$t_0$	$t_w$	$v_w$	Athlete	Date
1	w	10.67	10.54	+2.1	Florence Griffith-Joyner USA	25 Sep 1988
2		10.69	10.62	+1.0	Griffith-Joyner USA	24 Sep 1988
3		10.69	10.61	+1.2	Griffith-Joyner USA	17 Jul 1988
4	d	10.70	10.49	+4.0	Griffith-Joyner USA	16 Jul 1988
5		10.75	10.82	-1.0	Gail Devers USA	01 Aug 1992
6		10.76	10.83	-1.0	Juliet Cuthbert JAM	01 Aug 1992
7		10.77	10.84	-1.0	Irina Privalova RUS	01 Aug 1992
8		10.79	10.86	-1.0	Gwen Torrence USA	01 Aug 1992
9		10.80	10.87	-1.0	Merlene Ottey JAM	07 Aug 1991
10		10.80	10.82	-0.3	Ottey JAM	16 Aug 1993
11		10.81	10.70	+1.6	Griffith-Joyner USA	17 Jul 1988
12		10.81	10.84	-0.5	Devers USA	23 Aug 1996
13		10.81	10.78	+0.4	Ottey JAM	03 Sep 1994
14		10.83	10.74	+1.3	Ottey JAM	07 Sep 1996
15		10.83	10.77	+0.9	Privalova RUS	06 Jul 1994
16	A	10.84	10.79	+0.6	Evelyn Ashford USA	03 Jul 1983
17		10.84	10.84	+0.0	Ottey JAM	10 Jul 1991
18	A	10.85	10.78	+1.0	Dawn Sowell USA	03 Jun 1989
19		10.85	10.82	+0.4	Torrence USA	03 Sep 1994
20		10.85	10.85		Torrence USA	18 May 1996

Table 5: Women’s Top 20 fastest wind-corrected 100m times, including only wind-aided and altitude (A) performances. Griffith-Joyner’s 10.54s clocking has been assigned a wind reading of +2.1 m/s, since no accurate wind reading was found.

Rank		$t_W$	$W$	Athlete	Location	Date
1		9.84	+0.7	Donovan Bailey	Atlanta, GA	27 Jul 1996
2		10.03	+0.7	Bruny Surin	Paris, FRA	29 Jun 1996
3		10.16	+1.9	Glenroy Gilbert	Duisberg, GER	12 Jun 1996
4	A	10.18	+1.5	Robert Esmie	Colorado Sp., CO	08 Jun 1996
5		10.19	+0.8	Carlton Chambers	Eugene, OR	29 May 1996
6		10.30	+0.0	Andy Breton	Kalamazoo, MI	04 May 1996
7		10.37	+1.1	Peter Ogilvie	Austin, TX	04 May 1996
8	A	10.40	+0.5	Anthony Wilson	Flagstaff, AZ	11 May 1996
9		10.41	+1.0	Dave Tomlin	Montreal, PQ	21 Jun 1996
10		10.43	+1.8	Okiki Akinremi	Eich/Abbst., BC	02 Jun 1996
	w	9.88	+4.0	Donovan Bailey	Duisburg, GER	12 Jun 1996
	w	9.97	+2.1	Bailey	Atlanta, GA	18 May 1996
	w	10.08	+3.4	Robert Esmie	Kitchener, ON	09 Aug 1996
	w	10.39	+4.4	Esmie	Kitchener, ON	09 Aug 1996
	w	10.13	+4.0	Glenroy Gilbert	Duisburg, GER	12 Jun 1996
	w	10.18	+3.1	Carlton Chambers	College Park, MD	19 Apr 1996
	w	10.27	+3.4	Dave Tomlin	Kitchener, ON	09 Aug 1996

Table 6: Canadian Men's Top 10 fastest official 100m times, including altitude performances (A); wind-aided times are unranked.

New	Old		$t_0$	$t_W$	$W$	Athlete	Location	Date
1	1		9.88	9.84	0.7	Donovan Bailey	Atlanta, GA	27 Jul 1996
2	2		10.03	10.05	-0.4	Surin	Lausanne, SWI	03 Jul 1996
3	3		10.18	10.18	0.0	Gilbert	Montréal, PQ	21 Jun 1996
4	5		10.22	10.22	0.0	Chambers	Montréal, PQ	21 Jun 1996
5	4	w	10.26	10.08	3.4	Robert Esmie	Kitchener, ON	09 Aug 1996
6	6		10.30	10.30	0.0	Andy Breton	Kalamazoo, MI	04 May 1996
7	8	A	10.44	10.40	0.5	Anthony Wilson	Flagstaff, AZ	11 May 1996
8	7		10.44	10.37	1.1	Peter Ogilvie	Austin, TX	04 May 1996
9	11		10.44	10.44	0.0	Abass Tanko	Sherbrooke, PQ	08 Jun 1996
10	9	w	10.45	10.27	3.4	Dave Tomlin	Kitchener, ON	09 Aug 1996

Table 7: Canadian Men's Top 10 fastest wind-corrected 100m times, including altitude performances (A).

Rank	$t_0$	$t_W$	$W$	Athlete	Location	Date
1	9.88	9.84	0.7	Donovan Bailey	Atlanta, GA	27 Jul 1996
2	9.91	9.93	-0.4	Bailey	Lausanne, SWI	3 Jul 1996
3	9.97	10.00	-0.5	Bailey	Atlanta, GA	27 Jul 1996
4	9.98	9.98	+0.0	Bailey	Montréal, PQ	21 Jun 1996
5	10.03	10.05	-0.4	Surin	Lausanne, SWI	3 Jul 1996
6	10.04	9.95	1.5	Bailey	Milan, ITA	7 Sep 1996
7	10.04	10.04	0.0	Surin	Montréal, PQ	21 Jun 1996
8	10.06	10.13	-1.2	Surin	Atlanta, GA	26 Jul 1996
9	w 10.07	9.88	4.0	Donovan Bailey	Duisburg, GER	12 Jun 1996
10	10.08	10.03	0.7	Bruny Surin	Paris, FRA	29 Jun 1996
11	w 10.09	9.97	2.1	Bailey	Atlanta, GA	18 May 1996
12	10.18	10.18	0.0	Gilbert	Montréal, PQ	21 Jun 1996
13	10.20	10.11	1.5	Surin	Milan, ITA	7 Sep 1996
14	10.22	10.22	0.0	Chambers	Montréal, PQ	21 Jun 1996
15	10.24	10.19	0.8	Carlton Chambers	Eugene, OR	29 May 1996
16	w 10.26	10.08	3.4	Robert Esmie	Kitchener, ON	9 Aug 1996
17	10.26	10.22	0.6	Gilbert	Hechtel, BEL	6 Jul 1996
18	A 10.27	10.18	1.5	Robert Esmie	Colorado Sp., CO	8 Jun 1996
19	10.27	10.16	1.9	Glenroy Gilbert	Duisberg, GER	12 Jun 1996
20	10.28	10.28	0.0	Esmie	Montréal, PQ	21 Jun 1996
21	10.28	10.28	0.0	Esmie	Montréal, PQ	21 Jun 1996
22	10.30	10.30	0.0	Andy Breton	Kalamazoo, MI	4 May 1996
23	w 10.33	10.13	4.0	Glenroy Gilbert	Duisburg, GER	12 Jun 1996
24	10.34	10.23	1.8	Gilbert	Stockholm, SW	8 Jul 1996
25	w 10.35	10.18	3.1	Carlton Chambers	College Park, MD	19 Apr 1996
26	10.40	10.40	0.0	Esmie	Montréal, PQ	21 Jun 1996
27	10.42	10.35	1.0	Chambers	Montréal, PQ	21 Jun 1996
28	A 10.44	10.40	0.5	Anthony Wilson	Flagstaff, AZ	11 May 1996
29	10.44	10.37	1.1	Peter Ogilvie	Austin, TX	4 May 1996
30	10.44	10.44	0.0	Abass Tanko	Sherbrooke, PQ	8 Jun 1996

31	w	10.45	10.27	3.4	Dave Tomlin	Kitchener, ON	9 Aug 1996
32		10.46	10.46	-0.1	Esmie	Kerkrade, HOL	17 May 1996
33		10.48	10.41	1.0	Dave Tomlin	Montréal, PQ	21 Jun 1996
34		10.54	10.43	1.8	Okiki Akinremi	Eich/Abbost, BC	2 Jun 1996
35		10.55	10.52	0.4	Esmie	Stockholm, SW	8 Jul 1996
36		10.57	10.57	0.0	Bradley McCuaig	Montréal, PQ	21 Jul 1996
37		10.58	10.55	0.4	Trevino Betty	Montréal, PQ	21 Jun 1996
38		10.59	10.48	1.8	Chambers	Stockholm, SW	8 Jul 1996
39		10.59	10.59	0.0	Sheridan Baptiste	Baton Rouge, LA	11 May 1996
40		10.60	10.49	1.8	Ricardo Greenidge	Rich/Abbost, BC	2 Jun 1996
41		10.61	10.61	-0.1	Kofi Yevakpor	Sherbrooke, PQ	15 Jul 1996
42	w	10.61	10.39	4.4	Esmie	Kitchener, ON	9 Aug 1996
43		10.63	10.60	0.4	Charles Allen	Kitchener, ON	7 Jun 1996
44		10.67	10.64	0.4	Bryce Coad	Kitchener, ON	7 Jun 1996
45		10.70	10.63	1.0	Troy Dos Santos	Montréal, PQ	21 Jun 1996

Table 8: Canadian Men's Top fastest wind-corrected 100m times, including altitude performances (A).

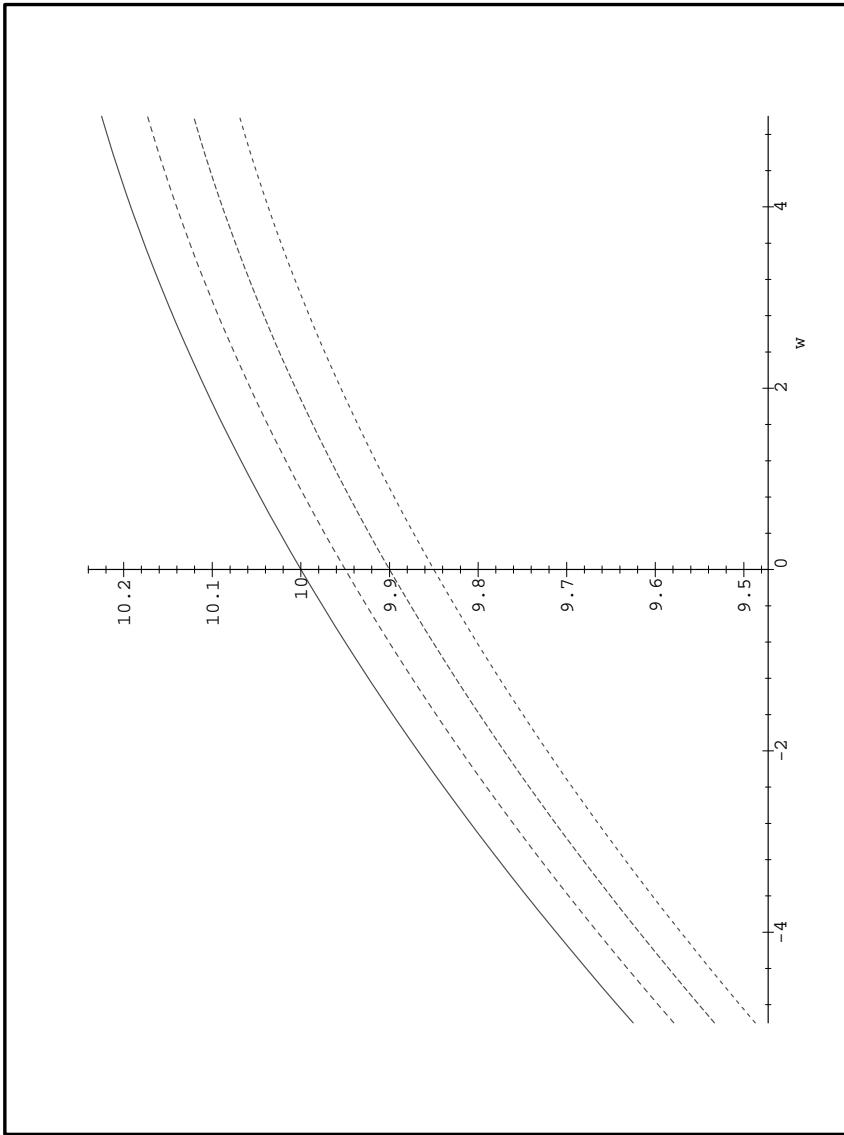


Figure 1: Wind-correction curves for wind-assisted times of 10.00s (upper solid), 9.95 (second), 9.90 (third), and 9.85 (bottom). Wind speed is  $w$ .